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POLICY RESEARCH WORKING PAPER 2913

Financial Development and Dynamic Investment Behavior

Evidence from Panel Vector Autoregression

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The World Bank
Development Research Group
Finance
October 2002

Abstract

Love and Zicchino apply vector autoregression to firm-level panel data from 36 countries to study the dynamic relationship between firms' financial conditions and investment. They argue that by using orthogonalized impulse-response functions they are able to separate the "fundamental factors" (such as marginal profitability of investment) from the "financial factors" (such as availability of internal finance) that influence the level of investment. The authors find that the impact of the financial factors on investment, which they interpret as evidence of financing constraints, is significantly larger in countries with less developed financial systems. The finding emphasizes the role of financial development in improving capital allocation and growth.

This paper—a product of Finance, Development Research Group—is part of a larger effort in the group to study access to finance. Copies of the paper are available free from the World Bank, 1818 H Street NW, Washington, DC 20433. Please contact Kari Labrie, room MC3-456, telephone 202-473-1001, fax 202-522-1155, email address klabrie@worldbank.org. Policy Research Working Papers are also posted on the Web at http://econ.worldbank.org. The authors may be contacted at ilove@worldbank.org or lea.zicchino@bankofengland.co.uk. October 2002. (32 pages)

Financial Development and Dynamic Investment Behavior: Evidence From Panel Vector Autoregression.

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1 Introduction

Unlike the neoclassical theory of investment, the literature based on asymmetric information emphasizes the role played by moral hazard and adverse selection problems in a firm's decision to invest in physical and human capital. As a result, the classical dichotomy between real and financial variables breaks down. In other words, financial variables can have an impact on real variables, such as the level of investment and the real interest rate, as well as propagate and amplify exogenous shocks to the economy. For example, Bernanke and Gertler (1989) show that a firm's net worth (a financial variable) can be used as collateral in order to reduce the agency cost associated with the presence of asymmetric information between lenders and borrowers. In this model, the firms' investment decisions are not only dependent on the present value of future marginal productivity of capital, as the q-theory approach predicts, but also on the level of collateral available to the firms when they enter a loan contract.

Since economists started to look at real phenomena abstracting from the Arrow-Debreu framework with its frictionless capital markets, a vast literature has been developed on the relationship between investment decisions and firms' financing constraints (see Hubbard, 1998, for a review). Even though asymmetric information between borrowers and lenders may be not the only source of imperfection in the credit markets, it remains a fact that firms seem to prefer internal to external finance to fund their investments. This observation leads to the prediction of a positive relationship between investment and internal finance. The first study on panel data by Fazzari, Hubbard and Peterson (1988) found that after controlling for investment opportunities with Tobin's q, changes in net worth affect investment more in firms with higher costs of external financing.

The link between the cost of external financing and investment decisions not only sheds light on the dynamics of business cycles but also represents an important element in understanding economic development and growth. For instance, in the presence of moral hazard in the credit market, firms that do not have internal funds and need to get a bank loan may be induced to undertake risky investment projects with low expected marginal productivity. This corporate decision affects the growth path of the economy, which may even get stuck in a poverty trap (see Zicchino, 2001). Recently, Rajan and Zingales (1998), Demirguc-Kunt and Maksimovic (1998) and Wurgler (2000) have looked at the link between finance and growth and have examined whether underdeveloped legal and financial systems could prevent firms from investing in potentially profitable growth opportunities. Their empirical results show that active stock market, developed financial intermediaries and the respect of legal norms are determinants of economic growth.

Estimation of the relationship between investment and financial variables is challenging because it is difficult for an econometrician to observe firms' net worth and investment opportunities. In theory, the measure of investment opportunities is the present value of expected future profits from additional capital investment, or what is commonly called marginal q. This is the shadow value of an additional unit of capital and it can be shown to be a sufficient statistic for investment. This is the 'fundamental' factor that determines investment policy of profit-optimizing firms in efficient markets. The difficulty in measuring marginal q, which is not observable, results in low explanatory power of the q-models and, typically, entails implausible estimates of the adjustment cost parameters.[1]

Another challenge is finding an appropriate measure for the 'financial' factors that enter into the investment equation in models with capital markets imperfections (such as adverse selection and moral hazard). A widely used measure for the availability of internal funds is cash flow (current revenues less expenses and taxes, scaled by capital). However, cash flow is likely to be correlated with the future profitability of the investment.[2] This makes it difficult to distinguish the response of investment to the 'fundamental' factors, such as marginal profitability of capital, and 'financial' factors, such as net worth (see Gilchrist and Himmelberg (1995 and 1998) for further discussion of this terminology).

In this paper we use the vector autoregression (VAR) approach to overcome this problem and isolate the response of investment to financial and fundamental factors. Specifically, we focus on the orthogonalized impulse-response functions, which show the response of one variable of interest (i.e. investment) to an orthogonal shock in another variable of interest (i.e. marginal productivity or a financial variable). By orthogonalizing the response we are able to identify the effect of one shock at a time, while holding other shocks constant.

[1]See Whited (1998) and Erikson and Whited (2000) for a discussion of the measurement errors in investment models. Also see Schiantarelli (1996) and Hubbard (1998) for a review on methodological issues related to investment models with financial contraints.

[2]For example, the current realization of cash flow would proxy for future investment opportunities if the productivity shocks were positively serially correlated.

We use firm-level panel data from 36 countries to study the dynamic relationship between firms' financial conditions and investment levels. Our main interest is to study whether the dynamics of investment are different across countries with different levels of development of financial markets. We argue that the level of financial development in a country can be used as an indication of the different degrees of financing constraints faced by the firms. After controlling for the 'fundamental' factors, we interpret the response of investment to 'financial' factors as evidence of financing constraints and we expect this response to be larger in countries with lower levels of financial development. To test this hypothesis we divide our data in two groups according to the degree of financial development of the country in which they operate. We document significant differences in the response of investment to 'financial' factors for the two groups of countries.

We believe our paper contributes to the literature on financial constraints and investment in several ways. First, by using vector autoregressions on panel data we are able to consider the complex relationship between investment opportunities and the financial situation of the firms, while allowing for a firm-specific unobserved heterogeneity in the levels of the variables (i.e. fixed effects). Second, thanks to a reduced form VAR approach, our results do not rely on assumptions that are necessary in models that use the q-theory of investment or Euler equations. Third, by analyzing orthogonalized impulse-response functions we are able to separate the response of investment to shocks coming form fundamental or financial factors. Finally, we contribute to the growth literature by presenting new evidence that investment in firms operating in financially underdeveloped countries exhibits dynamic patterns consistent with the presence of financing constraints. This finding highlights the role of financial development in improving capital allocation and growth.

Our paper is closely related to several recent papers. Gilchrist and Himmelberg (1995 and 1998) were the first to analyze the relationship between investment, future capital productivity and firms' cash flow with a panel-data VAR approach. They use a two-stage estimation procedure to obtain measures of what they call 'fundamental' q and 'financial' q. These factors are then substituted in a structural model of investment, which is a transformation of the Euler equation model. Unlike Gilchrist and Himmelberg, we do not estimate a structural model of investment, but instead study the unrestricted reduced-form dynamics afforded by the VAR (which is in effect the first stage in their estimation). Stanca and Gallegati (1999) also investigate the relationship between firms' balance sheets and investment by estimating reduced form VARs on company panel data for UK firms. Despite some differences in the specification of the empirical model and the estimation methodology, the approach and the results of their paper are similar to ours. However, they do not present an analysis of the impulse-response functions which we consider the main tool in separating the role of financial variables in companies' investment decisions. In addition, the distinguishing feature of our paper is the focus on the differences in the dynamic behavior of firms in countries with different levels of financial development.

Our paper is also related to Love (2002) who uses the Euler-equation approach and shows that financing constraints are more severe in countries with lower levels of financial development, the same as we find in this paper. However, the interpretation of the results in the previous paper is heavily dependent on the assumptions and parameterization of the model, while the approach we use here imposes the bare minimum of restrictions on parameters and temporal correlations among variables.

The rest of the paper is as follows: Section 2 presents the empirical methodology, Section 3 presents the data description; Section 4 provides the results and Section 5 presents our conclusions.

2 Empirical methodology

Our approach is to use a panel data Vector Autoregression (VAR) methodology. This technique combines the traditional VAR approach, which treats all the variables in the system as endogenous, with panel-data approach, which allows for unobserved individual heterogeneity. We present a discussion of the standard VAR model and the impulse-response functions in Appendix 1.

We specify a first-order three-variable VAR model as follows:

$$z_{it} = \Gamma_0 + \Gamma_1 z_{it-1} + f_i + d_{c,t} + e_t \tag{1}$$

where z_t is one of the two tree-variable vectors: $\{sk, ik, cfk\}$ or $\{sk, ik, cak\}$; sk is a sales to capital ratio and it is our proxy for the marginal productivity of the capital,[3]

[3]See Gilchrist, and Himmelberg (1998) for a derivation of the ratio of sales to capital as a measure of marginal productivity of capital.

ik is the investment to capital ratio which is our main variable of interest. We use two proxies for 'financial' factors: one is cfk which is cash flow scaled by capital, and the other one is cak, a ratio of cash stock to capital. Although cash flow is the most commonly used proxy for net worth it is closely related to operating profits and therefore also to marginal product of capital. If the investment expenditure does not result in higher sales but in lower costs (i.e. more efficiency), the sales to capital ratio would not pick up this effect, while the cash flow measure would. Thus, even in a VAR framework there is still a chance that cash flow would pick up a portion of the fundamental factor rather than financial factor. Therefore we prefer to use cash stock as our main proxy for 'financial' factors.

Since cash stock is a 'stock' rather than a 'flow' variable, it is much less likely to be correlated with fundamental factors than is cash flow. In addition, cash stock has an intuitive interpretation as "cash on hand" that firms can use for investment if the opportunities arrive. One theoretical justification for the cash stock measure appears in the Myers and Majluf (1984) model, where the amount of cash holdings, which the authors call "financial slack," has a direct effect on investment in the presence of asymmetric information. This slack allows firms to undertake positive NPV projects, which they would pass up if they did not have any internal funds. This implies that if external financing is costly, there will be a positive relationship between investment and cash stock.

We focus our analysis on the impulse-response functions, which describe the reaction of one variable in the system to the innovations in another variable in the system, while holding all other shocks at zero. However, since the actual variance-covariance matrix of the errors is unlikely to be diagonal, to isolate shocks to one of the VAR errors it is necessary to decompose the residuals in a such a way that they become orthogonal. The usual convention is to adopt a particular ordering and allocate any correlation between the residuals of any two elements to the variable that comes first in the ordering.[4] The identifying assumption is that the variables that come earlier in the ordering affect the following variables contemporaneously, as well as with a lag, while the variables that come later only affect the previous variables with a lag. In other words, the variables that appear earlier in the system are more exogenous and the ones that appear later are more endogenous.

In our specification we assume that current shocks to the marginal productivity of capital (proxied by sales to capital) have an effect on the contemporaneous value of investment, while investment has an effect on the marginal productivity of capital only with a lag. We believe this assumption is reasonable for two reasons. First, the sales is likely to be the most exogenous firm-level variable available since it depends on the demand for the firm's output, which often is outside of the firms' control (of course, sales depend on the firm's actions as well but most likely with a lag). Second, investment is likely to become effective with some delay since it requires time to become fully operational (so called a "time-to-build" effect). We also argue that the effect of sales on either cash flow or cash stock is likely to be contemporaneous and

[4]The procedure is know as Choleski decomposition of variance-covariance matrix of residuals and is equivalent to transforming the system in a "recursive" VAR for identification purposes. See Appendix 1 for the derivations and further discussion of impulse-responce functions.

if there is any feedback effect it is likely with a lag. Finally, we assume that cash stock responds to investment contemporaneously, while investment responds to cash stock with a lag. This is because the firm will consider last year's stock of cash while making this year's investment decision, while the end of year cash stock will definitely reflect the current year investment.[5]

Our analysis is implicitly based on an investment model in which, after controlling for the marginal profitability, the effect of the financial variables on investment is interpreted as evidence of financing constraints.[6] We do this informally, by relying on the orthogonalization of impulse-responses. Because the shocks are orthogonalized, in other words the 'fundamentals' are kept constant, the impulse response of investment to cash stock isolates the effect of the 'financial' factors.

Our main interest is to compare the response of investment to financial factors in countries on a different level of financial development. To do that we split our firms into two samples according to the level of financial development of the country in which they operate and study the difference in impulse-responses for the two samples. We refer to these two groups as 'high' (financial development) and 'low' (financial development), but this distinction is relative and is based on the median level of financial development among countries in our sample.[7]

In applying the VAR procedure to panel data, we need to impose the restriction

[5]We present the resutls of the model that includes cash flow in the same order for comparison purposes, however these results are robust to changing the order of cash flow and investment.

[6]See Gilchrist and Himmelberg (1998) for a more formal structural model that is behind their first-stage reduced VAR approach, which is similar to our approach.

[7]A recent paper by Powell et al. (2002) uses similar approach to ours (i.e. splitting the countries into two groups and estimating VARs separately for each group) to study the interrelationships between inflows and outflows of capital and other macro variables.

that the underlying structure is the same for each cross-sectional unit. Since this constraint is likely to be violated in practice, one way to overcome the restriction on parameters is to allow for "individual heterogeneity" in the levels of the variables by introducing fixed effects, denoted by f_i in the model. Since the fixed effects are correlated with the regressors due to lags of the dependent variables, the mean-differencing procedure commonly used to eliminate fixed effects will create biased coefficients. To avoid this problem we use forward mean-differencing, also referred to as the Helmert procedure (see Arellano and Bover 1995). This procedure removes only the forward mean, i.e. the mean of all the future observations available for each firm-year. Since this transformation preserves the orthogonality between transformed variables and lagged regressors, we use lagged regressors as instruments and estimate the coefficients by system GMM.[8]

Our model also allows for country-specific time dummies, $d_{c,t}$, which are added to the model (1) to capture aggregate, country-specific macro shocks that may affect all firms in the same way. We eliminate these dummies by subtracting the means of each variable calculated for each country-year.

To analyze the impulse-response functions we need some estimate of their confidence intervals. Since the matrix of impulse-response functions is constructed from the estimated VAR coefficients, their standard errors need to be taken into account. Since analytical standard errors are computationally difficult to implement, we report standard errors of the impulse response functions by using Monte Carlo simulation to

[8]In our case the model is "just identified," i.e. the number of regressors equals the number of instruments, therefore system GMM is numerically equivalent to equation-by-equation 2SLS.

generate their confidence intervals.[9] To compare the impulse-responses across our two samples (i.e. 'high' and 'low' financial development) we simply take their difference. Because our two samples are independent, the impulse-responses of the differences are equal to the difference in impulse-responses (the same applies to the simulated confidence intervals).

3 Data

Our firm-level data comes from the Worldscope database, which contains stardardized accounting information on large publicly traded firms and it contains 36 countries with over 7000 firms for the years 1988-1998. Table 1 gives the list of countries in the sample with the number of firms and observations per country, while details on the sample selection are given in Appendix 2. The number of firms included in the sample varies widely across the countries and the less developed countries are underrepresented. The US and UK have more than 1000 firms per country, while the rest of the countries have only 136 firms on average (Japan is the third largest with over 600 firms). Such a prevalence of US and UK companies will overweight these countries in the cross-country regressions and prevent smaller countries from influencing the coefficients. To correct for this we use only the largest firms within

[9] In practice, we randomly generate a draw of coefficients Γ of model (1) using the estimated coefficients and their variance-covariance matrix and re-calculate the impulse-resonses. We repeat this procedure 1000 times (we experimented with a larger number of repetitions and obtained similar results). We generate 5th and 95th percentiles of this distribution which we use as a confidence interval for each element of impulse-response. Stata programs used to estimate the model and generate impulse-response functions and their confidence intervals are available from the authors.

each country. The inclusion criteria are based on firm ranking, where rank 1 is given to the largest firm in each country. We limit our analysis to the largest firms in each countries because we want to compare firms of the same "type" across countries (i.e. large firms with large firms) to isolate any size effect.

We construct the index of financial development, FD by combining standardized measures of five indicators from Demirguc-Kunt and Levine (1996): market capitalization over GDP, total value traded over GDP, total value traded over market capitalization, the ratio of liquid liabilities (M3) to GDP and the credit going to the private sector over GDP. We split the countries into two groups based on the median of this indicator. We refer to these two groups as 'high' (financial development) and 'low' (financial development), but we remind the reader that this distinction is relative and is based on the median level of financial development among countries in our sample.

Table 2 summarises all the variables used in the paper (note that we normalize all the firm-level variables by the beginning-of-period capital stock), and Table 3 reports the distribution of cross-country firm level variables.

4 Results

The main results are reported in Tables 4 and 5. We report the estimates of the coefficients of the system given in (1) where the fixed effects and the country-time dummy variables have been removed. In Table 4 we report the results of the model with cash stock, while in Table 5 we report the model with cash flow. We report the results that include only up to 150 largest firms in each country using a rank-based approach described in the data section.[10] We present graphs of the impulse-response functions and the 5% error bands generated by Monte Carlo simulation. Figure 1 reports graphs of impulse-responses for the model with cash stock estimated for a sample of countries with 'low' financial development, while Figure 2 reports this model for countries with 'high' financial development. In Figure 3 we show the differences in impulse-responses of two samples for a model with cash stock (the difference is 'low' minus 'high'). To save space we do not present graphs for the model with cash flow separately for each sample but only report the differences in impulse-responses in Figure 4.

We discuss general results first before moving on to the results of our particular interest. We observe that the response of sales to capital ratio to investment is negative in the estimated coefficeints and impulse-responses. This is expected as sales to capital is our proxy for marginal product of capital. A shock to investment increases the capital stock, which moves the firm along the production frontier. With diminishing returns to capital, the marginal product will decrease.

The investment shows an expected positive response to a shock in sales to capital ratio (i.e. marginal profitability), both in the estimated coefficients and in the impulse-responses (but in the later the positive response is only with a one-year lag

[10]We have repeated our analysis with other models where we have considered different proxies for both cash flow and cash stock, and different normalizations (for example, scaling by total assets instead of capital stock). The results are similar to the ones reported and are available on request. We also used different cutoff points - such as 50 or 100 firms and obtained similar results (available on request).

because of the negative contemporaneous correlation).[11] Cash stock is increasing in response to sales shock (higher revenues allow more cash to be kept in cash stock), while it is decreasing in response to investment (as investment is a major use of cash, larger invesment implies that there will be less cash left at the end of the year). Cash stock has no significant effect on sales to capital (and there is no reason to expect such an effect). All the patterns that we observe are very similar across our two groups of countries.

The result of particular interest is the response of investment to financial variables-the cash stock or cash flow. We first observe that the impact of the lagged cash stock (as well as cash flow) on the level of investment is much larger in countries qith 'low' financial development than it is in countries with 'high' levels. This difference is most pronounced in the model with cash stock in which the coefficients are almost three times larger in the 'low' sample (i.e. 0.036 compared with 0.013 - see last column in Table 4), and this difference is statistically significant. This is the first evidence that financial factors have a different effect on investment in countries with different levels of financial development.

The panels representing the impulse-response of investment, ik, to a one standard deviation shock in cash stock, cak, clearly show a positive impact. We also notice that this response has a larger impact on the value of the investment for firms in

[11]In the results reported we scaled all the variables by current period capital stock. This leads to the contemporaneous negative response of investment to sales to capital, which is purely mechanical and driven by the scaling factor. This response is positive when we scale all our results by the end of the previous period capital stock. All our results hold when we scale by end of the previous period capital stock.

'low' sample. This can be seen most clearly in Figure 3 that reports the difference in two samples responses (i.e. 'low' minus 'high'). The difference between two impulse-responses is significant at better than 5% (i.e. the 5% lower band is quite above the zero line). The same is true when we use a model with cash flow instead of cash stock (Figure 4), however the difference is a little less pronounced.

The orthogonalization of the VAR residuals (discussed in section 2) allows us to isolate the response of investment to 'financial' factors (cash stock or cash flows) from the response to 'fundamental' factors (marginal productivity of capital). We can therefore interpret our results as evidence that the response of investment to 'financial' factors and therefore the intensity of financing constraints is significantly larger in countries with less developed financial markets.

In conclusion, both the coefficient estimates resulting from the Vector Autoregressions and the impulse-response functions support our claim that in the presence of financing constraints, which are clearly more stringent in countries that don't have a well developed financial system, the availability of liquid assets affects firms' investment decisions. This implies that financial under-development adversely affects the dynamic investment behavior which leads to inefficient allocation of capital.

5 Conclusions

This paper uses a VAR approach to the analysis of firm-level data and shows that the availability of internal liquid funds matters more when firms make investment decisions in countries where the financial system is not well developed. More specifically, we find that the impact of a positive shock to cash stock or cash flow is significantly higher for firms in countries with lower level of financial development. Since the investment level of firms that are more constrained in their ability to obtain external financing is affected by shocks to internal funds, the accumulation of capital will be less efficient in countries that are less financially developed, thus leading to slower economic growth.

We believe our paper contributes to the literature on financial constraints and investment decisions as well as to the finance and growth literature. Thanks to a reduced form VAR approach, we do not need the strong assumptions that are necessary in models that use the q-theory of investment or the Euler-equation approach. Moreover, by analyzing impulse-response functions we are able to separate the fundamental from the financial factors that influence the level of investment, overcoming the problems stemming from the potential correlation between the proxy for net worth and the investment opportunities. Our findings highlight the role of financial development in improving capital allocation and growth.

Appendix 1. VAR with Panel Data

A VAR is a multivariate simultaneous equation system, in which each variable under study is regressed on a finite number of lags of all variables jointly considered. The VAR approach is useful when the intention is to analyze a phenomenon without having any strong priors about competing explanations of it. The method focus on deriving a good statistical representation of the interactions between variables, letting the data determine the model. In a simple two-variable case, a first-order vector autoregression model can be written as follows:

$$x_t = a_{10} - a_{12}y_t + \beta_{11}x_{t-1} + \beta_{12}y_{t-1} + \epsilon_{xt} \tag{2}$$

$$y_t = a_{20} - a_{21}x_t + \beta_{21}x_{t-1} + \beta_{22}y_{t-1} + \epsilon_{yt} \tag{3}$$

The time path of $\{x_t\}$ is affected by current and past values of the sequence $\{y_t\}$ and the time path of $\{y_t\}$ is affected by current and past realizations of the sequence $\{x_t\}$. The errors ϵ_{xt} and ϵ_{xt} are uncorrelated white-noise disturbances with constant variances. We can rewrite this system as:

$$\begin{bmatrix} 1 & a_{12} \\ a_{21} & 1 \end{bmatrix} \begin{bmatrix} x_t \\ y_t \end{bmatrix} = \begin{bmatrix} a_{10} \\ a_{20} \end{bmatrix} + \begin{bmatrix} \beta_{11} & \beta_{12} \\ \beta_{21} & \beta_{22} \end{bmatrix} \begin{bmatrix} x_{t-1} \\ y_{t-1} \end{bmatrix} + \begin{bmatrix} \epsilon_{xt} \\ \epsilon_{yt} \end{bmatrix} \tag{4}$$

or in a more compact form:

$$Az_t = \Lambda_0 + \Lambda_1 z_{t-1} + \epsilon_t \tag{5}$$

The model represented by equations (2) and (3) is called a "structural" VAR under presumption that there exists some underlying theory that provides restrictions on the matrix A and allows to identify the coefficients. In fact, these equations cannot be estimated directly due to the correlation of x_t with ϵ_{yt} and of y_t with ϵ_{xt}. If we premultiply the system in (5) by A^{-1}, we obtain the so-called standard "reduced" form:

$$z_t = \Gamma_0 + \Gamma_1 z_{t-1} + e_t \tag{6}$$

where, $\Gamma_0 = A^{-1}\Lambda_0$; $\Gamma_1 = A^{-1}\Lambda_1$ and $e_t = A^{-1}\epsilon_t$. In the standard form of the model, the errors e_t are composites of the white-noise processes ϵ_t and therefore have zero means, constant variances and are individually serially uncorrelated. However, the covariance of the e_{1t} and e_{2t} shocks are not in general equal to zero. The VAR model in standard form does not present the estimation problems of the structural form. The OLS method gives unbiased estimates of the elements of the matrices Γ_0 and Γ_1, and of the variance-covariance matrix of the errors $\{e_t\}$. However, the estimation of the standard model yields fewer estimates than the number of parameters of the primitive model. Therefore, to identify the system some restrictions on the parameters of the structural model are necessary (for example, we might impose that one of the parameters be equal to zero).

The impulse response functions are based on the moving average representation of the system, which is the following:

$$z_t = \mu + \sum_{i=0}^{\infty} \Gamma_1^i e_{t-i} \tag{7}$$

where μ is a function of the parameters of the model and Γ_1^i is the i^{th} power of the matrix Γ_1 from equation (6). However, this representation would not be very useful to study the effect of changes in, say, e_{yt} on either $\{x_t\}$ or $\{y_t\}$ because the errors are correlated and therefore tend to move together. Since the errors $\{e_{t-i}\}$ are a function of the original shocks $\{\epsilon_{xt}\}$ and $\{\epsilon_{yt}\}$, we can rewrite z_t as:

$$z_t = \mu + \sum_{i=0}^{\infty} \phi_i \epsilon_{t-i} \tag{8}$$

The coefficients ϕ_i are the impulse-response functions. In a two-variable case, $\partial z_t / \partial \epsilon_{t-s} = \phi_s$ is a matrix where, for example, the element $\phi_{s,xy}$ represents the impact of a unit shock in $\epsilon_{y,t-s}$ on x_t. To quantify the cumulative response of an element of z_t to an unpredicted innovation in some component of ϵ_t, the components of ϵ_t must be orthogonal. If we assume that the $\Omega = E(\epsilon_t \epsilon_t')$ is positive definite, then there exists a unique lower triangular matrix K with ones along the principal diagonal and a unique diagonal matrix D with positive entries along the principal diagonal, such that:

$$\Omega = KDK' \tag{9}$$

Let

$$u_t = K^{-1}\epsilon_t. \tag{10}$$

Then $E\left(u_t u_t'\right) = K^{-1}\Omega\left(K^{-1}\right)' = D$. Since $\epsilon_t = Ku_t$, the vector $\{z_t\}$ has a moving average representation in terms of u_t:

$$z_t = \mu + \sum_{i=0}^{\infty} K\phi_i u_{t-i} \tag{11}$$

For example in two-variable case, we will have that

$$\frac{\partial y_t}{\partial u_{x,t-s}} = \phi_s K_x, \tag{12}$$

where K_x is the first column of the matrix K. The plot of (12) as a function of $s > 0$ is an orthogonalized impulse response function.

Appendix 2. Sample Selection

All countries in the Worldscope database (May 1999 Global Researcher CD) with at least 30 firms and at least 100 firm-year observations are included in the sample (in addition we include Venezuela (VE), though it has only 80 observations); former socialist economies are excluded. This results in a sample of 40 countries. The sample does not include firms for which the primary industry is either financial (one digit SIC code of 6) or service (one digit SIC codes of 7 and above).

In addition we delete the following (see Table 2 for variable definitions):

- All firms with 3 or less years of coverage;

- All firm-years with missing CAPEX, Sales, Netpeq, Compnumb or Cash;

- Observations with negative Cash (2 obs), Stminv (1 ob), SK (2 obs) or Depre (26 obs);

- Observations with DAK > 0.7 (2018 obs);

- Outliers for the distributions of SK, IK, CAK and CFK

The resulting dataset has about 54,000 observations. The number of observations by country is given in Table 1.

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Table 1. Sample Coverage Across Countries

Countries are split into two groups based on the median level of financial development.

Country	Country code	Number of observations	Percent of total observations	Number of firms	Number of observations, if rank<150	Percent of total if rank<150	Financial development
Panel A: Low Financial development sample							
Argentina	AR	250	0.004	39	250	0.006	-1.38
Belgium	BE	586	0.01	91	586	0.01	-0.82
Brazil	BR	894	0.01	143	894	0.02	-1.04
Chile	CL	507	0.01	74	507	0.01	-0.75
Colombia	CO	146	0.00	21	146	0.003	-1.6
Denmark	DK	1,051	0.02	138	1051	0.02	-0.49
Finland	FI	818	0.01	113	818	0.02	-0.41
Indonesia	ID	708	0.01	114	708	0.02	-1.17
India	IN	1,856	0.03	294	1,152	0.03	-0.7
Italy	IT	1,100	0.02	151	1100	0.03	-0.64
Mexico	MX	522	0.01	76	522	0.012	-0.85
New Zealand	NZ	304	0.005	44	304	0.01	-0.53
Philippines	PH	406	0.006	68	406	0.01	-1.15
Pakistan	PK	546	0.01	88	546	0.01	-1.28
Portugal	PT	291	0.004	53	291	0.01	-0.67
Sweden	SE	1,178	0.02	178	1178	0.03	-0.31
Turkey	TR	248	0.004	54	248	0.006	-1.2
Venezuela	VE	92	0.001	13	92	0.002	-1.26
GROUP AVERAGE		*639*	*0.010*	*97*	*600*	*0.014*	*-1*
GROUP TOTAL		*11,503*		*1,752*	*10,799*		
Panel B: High Financial development sample							
Austria	AT	530	0.01	83	530	0.01	-0.27
Australia	AU	1,383	0.02	184	1,355	0.03	0.42
Canada	CA	3,136	0.05	443	1,603	0.04	0.03
Switzerland	CH	1,087	0.02	151	1087	0.02	2.2
Germany	DE	4,092	0.06	582	1,636	0.04	1.68
Spain	ES	987	0.01	134	987	0.02	-0.14
France	FR	3,338	0.05	524	1,562	0.04	0.1
United Kingdom	GB	8,657	0.13	1165	1,521	0.03	1.68
Israel	IL	164	0.00	37	164	0.004	0.01
Japan	JP	6,654	0.10	1271	1,443	0.03	3.3
South Korea	KR	1,643	0.02	259	1329	0.03	0.84
Malaysia	MY	1,837	0.03	291	1,287	0.03	1.19
Netherlands	NL	1,282	0.02	154	1,282	0.03	0.66
Norway	NO	878	0.01	148	878	0.02	-0.15
Singapore	SG	906	0.01	145	906	0.02	1.6
Thailand	TH	1,233	0.02	185	1215	0.03	0.36
USA	US	3,399	0.05	356	1,554	0.04	1.35
South Africa	ZA	1,189	0.02	244	1154	0.03	0.25
GROUP AVERAGE		*2,355*	*0.036*	*353*	*1,194*	*0.027*	*1*
GROUP TOTAL		*42,395*		*6,356*	*21,493*		
Total Sample		66,040		9,957	43,691		

Table 2. Variable Definitions

Abbreviation	Description
Firm Level variables (from Worldscope)	
CAPEX	Capital expenditure
NETPEQ	Property Plant and Equipment
SALES	Net Sales or Revenues
IK	Investment to Capital ratio = CAPEX / NETPEQ
SK	Sales to Capital ratio = SALES /NETPEQ
CF	Cash Flow (derived from WorldScope cash flow to sales ratio)
CAK	Cash Stock divided by NETPEQ
CFK	Cash Flow divided by NETPEQ
RANK	Ranking based on size of PPENT (first, ranked by year, then averaged over the years), largest firm in each country has rank equal to one
Country-Level variables	
STKMKT	Stock market development is Index1 from Demirguc-Kunt and Levine (1996), equals to the sum of (standardized indices of) market capitalization to GDP, total value traded to GDP, and turnover (total value traded to market capitalization).
FININT	Financial intermediary development is Findex1 from Demurguc-Kunt and Levine (1996), equals to the sum of (standardized indices of) ratio of liquid liabilities to GDP, and ratio of domestic credit to private sector to GDP.
FD	Financial Development = STKMKT+FININT.

Table 3. Distribution of Main Variables

Summary statistics for two groups of countries including only up to the top 150 largest firms in each country. Variable definitions are given in Table 2. Countries are split into two groups based on the median level of financial development.

	Low Financial Development sample					High Financial Development sample				
	Mean	Standard Deviation	25th Percentile	50th Percentile	75th Percentile	Mean	Standard Deviation	25th Percentile	50th Percentile	75th Percentile
SK	3.39	3.54	1.06	2.31	4.38	4.12	4.05	1.41	2.92	5.33
IK	0.21	0.15	0.10	0.17	0.28	0.21	0.14	0.11	0.18	0.27
CAK	0.37	0.56	0.05	0.15	0.43	0.39	0.59	0.06	0.17	0.45
CFK	0.29	0.32	0.11	0.22	0.38	0.28	0.28	0.13	0.23	0.38

Table 4. Main Results of a VAR with Cash Stock

Variable definitions are in Table 2. Three variable VAR model is estimated by GMM, country-time and fixed effects are removed prior to estimation (see Section 2 for details). The firms are ranked on the basis of fixed assets and our model includes only up to the top 150 largest firms in each country. Countries are split into two groups based on the median level of financial development. Heteroskedasticity adjusted t-statistics are in parentheses.

Panel A: Low Financial development sample

Response to:	SK(t-1)	IK(t-1)	CAK(t-1)
Response of:			
SK(t)	0.540	-0.374	-0.063
	(8.11)***	(-3.01)***	(-.74)
IK(t)	0.002	0.214	0.036
	(0.79)	(14.62)***	(4.78)***
CAK(t)	0.008	-0.037	0.392
	(.76)	(-1.07)	(11.77)***
N obs	6920		
N firms	1430		

Panel B: High Financial development sample

Response to:	SK(t-1)	IK(t-1)	CAK(t-1)
Response of:			
SK(t)	0.564	-0.495	-0.022
	(12.52)***	(-3.63)***	(-0.30)
IK(t)	0.005	0.273	0.013
	(2.93)***	(22.1)***	(2.67)***
CAK(t)	0.017	-0.150	0.445
	(2.21)**	(-4.48)***	(16.34)***
N obs	14820		
N firms	2549		

Table 5. Main Results of a VAR with Cash Flow

Variable definitions are in Table 2. Three variable VAR model is estimated by GMM, country-time and fixed effects are removed prior to estimation (see Section 2 for details). The firms are ranked on the basis of fixed assets and our model includes only up to the top 150 largest firms in each country. Countries are split into two groups based on the median level of financial development. Heteroskedasticity adjusted t-statistics are in parentheses.

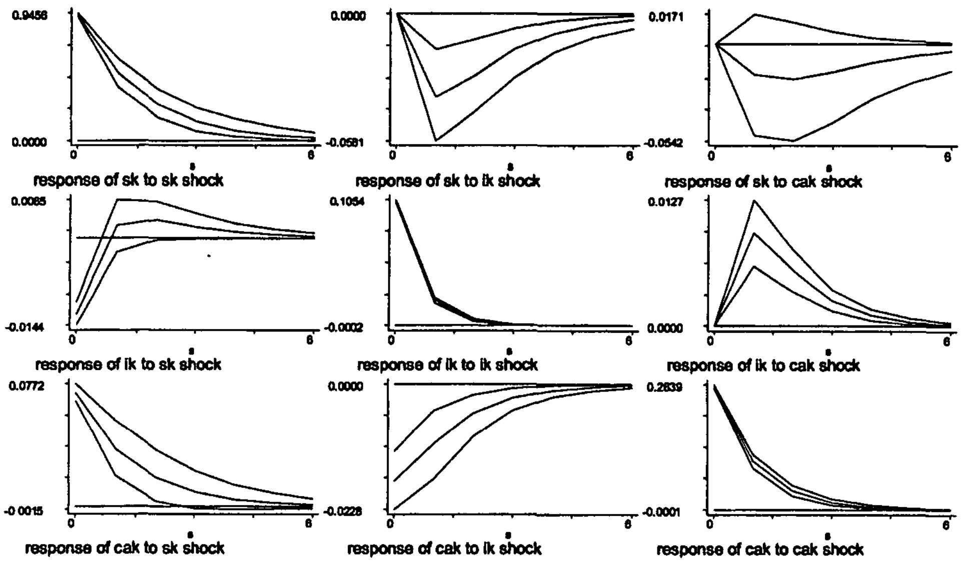
Panel A: Low Financial development sample

Response to:	SK(t-1)	IK(t-1)	CFK(t-1)
Response of:			
SK(t)	0.515	-0.394	0.183
	(6.96)***	(-3.34)***	(0.98)
IK(t)	-0.003	0.198	0.085
	(-.90)	(13.63)***	(6.40)***
CFK(t)	0.027	0.009	0.300
	(3.29)***	(.43)	(9.74)***
N obs	6858		
N firms	1427		

Panel B: High Financial development sample

Response to:	SK(t-1)	IK(t-1)	CFK(t-1)
Response of:			
SK(t)	0.573	-0.434	0.024
	(12.01)***	(-3.24)***	(0.159)
IK(t)	0.003	0.264	0.062
	(1.55)	(21.3)***	(6.92)***
CFK(t)	0.013	-0.045	0.345
	(2.89)***	(-2.17)	(15.76)***
N obs	14312		
N firms	2526		

Figure 1: Impulse-responses for Low Financial Development sample (model with cash stock)



Errors are 5% on each side generated by Monte-Carlo with 1000 reps

Figure 2: Impulse-responses for High Financial Development sample (model with cash stock)

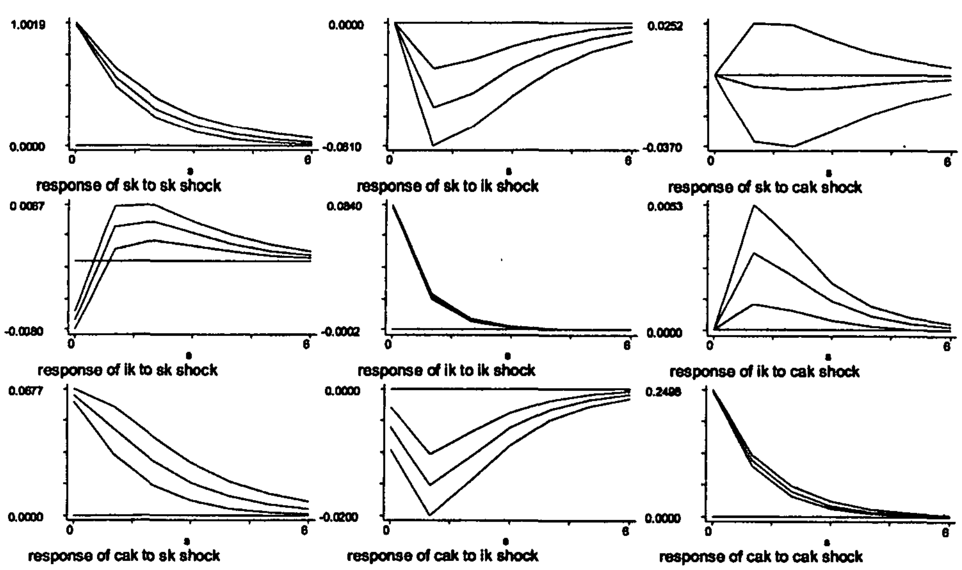


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Figure 3: Difference in Impulse-responses (Low – High) for a model with cash stock.

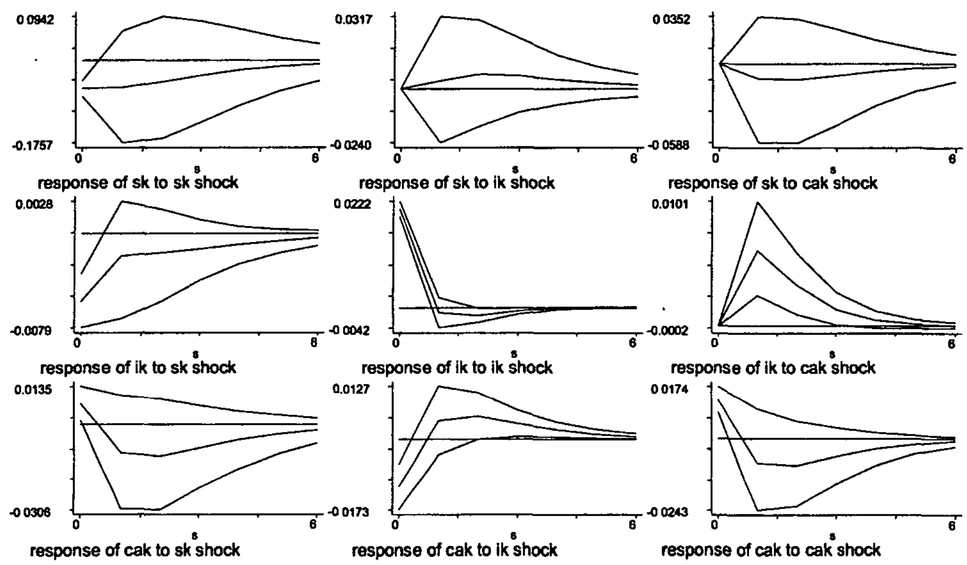

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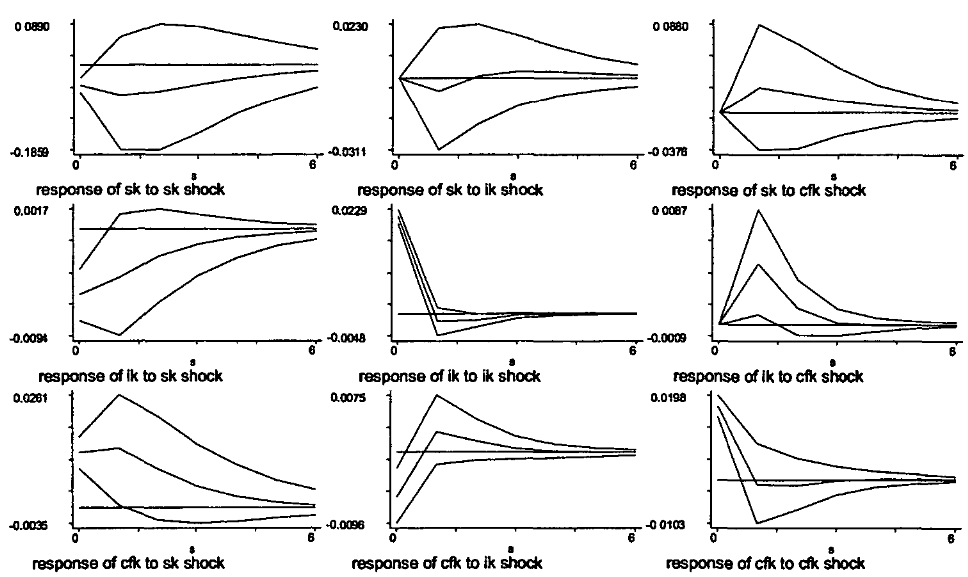
Figure 4: Difference in Impulse-responses (Low – High) for a model with cash flow.



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